GEOLOGY 412 Science and Engineering Field Applications ONLINE (3 credits) South Dakota School of Mines & Technology Black Hills Natural Sciences Field Station

Course Outline for Online Field Methods Course
Summer 2020

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Instructors: Mr. Scott Cooper, Drs. Yann Gavillot, Jon Rotzien, Ryan Sincavage, Umit Yildiz, and Nuri Uzunlar

Recommended course prerequisites: Physical Geology, Mineralogy, Petrology, Stratigraphy, Sedimentology and Structural Geology.

Recommended text: Compton, R. R., 1985, Geology in the Field: New York, John Wiley & Sons, 416 p., ISBN 0471829021.

GENERAL COURSE OPERATIONS

This course has been divided into four modules to introduce you to some of the basic concepts and methods of geologic field mapping. Each module consists of a number of projects that will take anywhere from a few hours to a full day to complete. The requirements and deliverables for each module will be determined by each individual instructor, but generally speaking your daily schedule for the duration of the course is as follows:

1.) Morning full class zoom meeting to introduce the topic(s) for the day and answer questions from the previous day's exercise(s)
2.) Lecture videos and demonstrations to help you proceed with the exercise(s) for that day
3.) Several hours of working time with your partner
4.) Afternoon check-in with a group of ~8-10 students for extra help with project(s)

Your instructor will provide you will a detailed rubric for each project that outlines the expectations for the deliverables. You will also be required to attend and participate in all online lectures and meetings as part of your overall grade. The point totals for each project will be provided to you before you begin.

All of the materials that you need for this course are posted on the D2L site. All assignments will be turned in digitally through the D2L dropbox. Some course materials and dropboxes will only be available for a limited time- it is your responsibility to make sure you understand all course deadlines and turn in your work on time.

This is an intensive online course that will require many hours of time commitment from each of you every day. For those of you attending the face-to-face (f2f) field camp in the Black Hills immediately after this course, we are requesting that you ***self-quarantine for the duration of this course***. This is in the interest of the health and safety of everyone you will interact with at the f2f camp. ***If you come to camp and are symptomatic, you will be forced to quarantine on campus or sent home and you will not receive credit for the f2f course.*** Don't jeopardize your chance at attending a f2f camp this summer, and more importantly, think of the well-being of those around you by staying home while taking the online course.

GRADING

On each day of the course you will be evaluated both on your attendance for online lectures/discussions and on the projects/exercises due for that day. Each day has a maximum point total of **100 points**, of which **5 come from the morning lecture and 5 from the afternoon check-in.** As such, keep in mind that attendance is important and accounts for **10% of your overall grade in the course**. There are 14 days in this course, so the maximum number of points you can earn is 100 x 14 = **1400 points.** Your final grade will be based on your total number of earned points as a percentage out of 1400 possible points.

GENERAL COURSE OUTLINE

MODULE 1: **Introduction to field methods: Basic concepts: Days 1-3 (June 28-30) – Instructors: Drs. Yildiz and Uzunlar**

Day ONE (June 28):

Lecture 1: Measuring and plotting geologic field data. Exercise using a Brunton compass or mobile device. Locating oneself in the field, understanding topo maps and using GPS instruments and plotting GPS data. Video demonstration with Brunton and mobile devices and GPS

Exercise 1. Using a Brunton compass or mobile device and measuring strike and dip on books or boards in the house or in the yard. Recording and plotting measured data using symbols.

Lecture 2**:** Pace and Brunton exercise.

Exercise 2. Understanding scale, orientation and plotting data: Plotting Pace and Brunton data.

Day TWO (June 29):

Lecture 3: Fundamentals of geologic mapping: Understanding topographic maps, valleys, ridges, contour lines, V-rule. Geologic data recording on field notebook and field sketches.

Exercise 3. Mapping contacts on topographic base maps.

Day THREE (June 30):

Lecture 4: Geologic maps and cross sections: Understanding / reading geologic maps, cross sections, symbols and other components, map types and uses.

Exercise 4. Simple x-section exercise. Recognizing, following and recording units, plotting data and sketching unit/formation boundaries. Google images and overlapping geologic maps will be utilized.

MODULE 2: **Field Mapping of Sedimentary Rocks and Stratigraphy: Days 4-7 (July 1-4) – Instructors: Drs. Rotzien and Sincavage**

Day FOUR (July 1):

Lecture 1: Inferring geologic contacts from landscape morphology, understanding regional-scale stratigraphic relationships, overview of Keweenawan Supergroup stratigraphy and geologic history of Lake Superior region, Using Google Earth to identify regional-scale geologic features, inferring unconformities, faults, and other contacts where surface observations are limited, including color changes on aerial imagery and land surface morphology changes

Project 1: Virtual mapping exercise, Keweenaw Peninsula, Michigan, USA, tracking an unconformity across the northern peninsula, inferring stratigraphy and structure at a regional scale

Day FIVE (July 2):

Lecture 2: Introduction to sedimentary geology in the field; sedimentation mechanics; sedimentary textures

Project 2: Introduction to sedimentary geology in the field, outcrop sketch and weathering profile, rock descriptions based on panoramas and close-up hand-sample images of rocks from the Alpine foreland basin of southeast France

Day SIX (July 3):

Lecture 3: Sedimentary structures, depositional environments and correlation techniques

Project 3: Virtual mapping exercise, Coalinga, California outcrop correlation, rock descriptions based on panoramas and close-up hand-sample images of rocks from the San Joaquin Basin

Day SEVEN (July 4):

Lecture 4: Using Gigapan and high-resolution photography to measure stratigraphic features, cyclicity and tidal signatures in stratigraphy, stratigraphic framework of southern West Virginia, focusing on the Pride Formation to distributary mouth bar succession.

Project 4. Multiple scales of cyclicity in clastic stratigraphy, navigating and measuring stratigraphic information on Gigapan imagery and photos, identifying cyclicity using basic statistical measures, interpretation of cycles in clastic stratigraphy

MODULE 3: **Introduction to Natural Fractures: Day 8 (July 5) Instructor: Mr. Scott Cooper**

Introduction: This module is designed to provide a basic working knowledge of fracture characteristics and variability. Various types of fractures, including regional and structure-related fractures will be discussed, as well as the distributions of fractures in different lithologic and structural settings and how they influence bulk porosity and fluid flow with application to petroleum systems.

Objectives: Students will learn the following:

- Different fracture types have different effects on reservoir permeability.
- Not all fractures of the same type are effective in enhancing reservoir permeability.
- Fracture types can vary by lithology within the same structural setting.
- Fracture types can vary by structural setting within the same lithology.
- An appreciation of the wide range of structures that fall under the basket term "fracture".

Lecture 1: **Understanding Fractures**: Discussion of fracture types and variability with implications for fluid flow in the following outline.

1. Extension fractures
2. Shear fractures/Faults
3. Deformation bands
4. Mineralization/Dissolution
5. Fractures in core

Exercise 1. Estimating remnant fracture porosity (% void space)

Exercise 2. Calculating the % of the rock that is porosity created by fractures

Exercise 3. Core photographs and questions

Lecture 1: **Evaluating Fractures**: Discussion of evaluating fractures in outcrop and how to extrapolate that information to the subsurface with implications for hydrocarbon production in the following outline.

1. Collecting and analyzing outcrop data
2. Extrapolating from the surface to the subsurface
3. Extension fractures in flat-lying strata
4. Mechanical Stratigraphy: Fractures in carbonates vs sandstone
5. Mechanical Stratigraphy: Fractures in resource-play shales
6. Case Study: Teapot Dome, Wyoming (plus reading assignment)

Exercise 4. Plotting and analyzing data on a rose diagram

Exercise 5. Plotting and analyzing data on a stereonet

MODULE 4: Mapping Geological Structures: Days 9-13 (July 6-10) – Instructors: Drs. Gavillot and Yildiz

Day NINE (July 6):

Lecture 1: Folds, tectonic context of folds, anticlines/synclines, geometric properties of folds, fold classification, Fleuty diagram, kinematic analysis of folds, recognizing folds from map patterns and from the field, demonstration visualizing in 3-D bedding and fold geometries using a customized Google Earth interface.

Project 1: Complete worksheet and activity of the 'Fold Analysis Challenge' on the Sheep Mountain anticline, Wyoming.

Day TEN (July 7):

Lecture 2: Demonstration using Google Earth for virtual mapping.

Project 2: Introduction to mapping geologic structures on folds, in the Zagros fold-thrust belt. Produce a simplified geologic map on a DEM with strikes/dips and fold hinge, and write a brief geological report, including a cross section diagram.

Day ELEVEN (July 8):

Lecture 3: Preparing a geologic cross-section, using stereonets to determine fold geometry.

Project 3: Mapping geologic structures using multiple datasets on folds, in the Atlas Mountains of Morocco. Produce geological maps on satellite and DEM, structural cross-section, and stereonet analysis, and a geological report.

Day TWELVE (July 9):

Lecture 4: Faults, tectonic context of faults, types of faults, Anderson theory- principal stress directions, anatomy of a fault zone, fault rocks, map and subsurface expression of faults, characterizing faults and sense of slip on strike-slip faults, lateral fault separation, topographic expression of strike-slip faults, virtual vs. field mapping of slip.

Project 4: Introduction to mapping geologic structures on faults, San Andreas fault, Wallace Creek CA, USA. Produce a Quaternary fault map using LiDAR, annotated with geologic offset using stream channels for Wallace Creek and at least 5 other offset channels, and a brief report of the results.

Day THIRTEEN (July 10):

Lecture 5: Faults (continued), characterizing sense of slip on dip-slip faults (normal and reverse faults), vertical fault separation, topographic expression, virtual vs. field mapping of slip.

Project 5: Mapping geologic structures from multiple dataset on faults, Owens Valley, Eastern California, CA, USA. Produce a geological map on LiDAR, structural cross-section, annotating maps and cross-sections with fault measurements, and a geological report.

Day FOURTEEN (July 11):

Final Mapping Project.

Above: Cliff exposures of the Pennsylvanian-Permian Minnelusa Formation, Beulah, Wyoming.

Above: Oligocene-Miocene outcrops of the Chadron, Brule and Arikaree formations, South Dakota.